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Specification and Drawings, as originally filed, with Application for Patent Serial No:  
2,286,892, on October 15, 1999, by FANTOM TECHNOLOGIES INC., assignee of  
Wayne Ernest Conrad, for "Method of Charging Secondary Batteries".

CA00/1183

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October 23, 2000

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## ABSTRACT OF THE DISCLOSURE

A method and apparatus are provided for charging secondary batteries. The method comprises modifying a DC voltage to form a pulse train, and supplying the modified DC voltage to the secondary cell.

- 5 Additionally, with one or more parameters, such as frequency, pulse width and amplitude, the pulse train can be selected and optimized, to optimize charging of the battery.
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**Title: METHOD OF CHARGING SECONDARY BATTERIES****FIELD OF THE INVENTION**

This invention relates to a method and apparatus for charging secondary cells or batteries.

**5   BACKGROUND OF THE INVENTION**

Secondary cells or batteries, as compared to primary cells, are designed to be capable of a large number of cycles of charging and discharging. A wide variety of secondary cells or batteries are known. For example, one common design is a so-called nickel-cadmium battery. This is  
10 a sealed battery having nickel anode, a cadmium cathode, and an alkaline electrode.

Like all batteries or cells, it delivers a DC current. Accordingly, charging of such secondary cells is commonly done by connection to a suitable, fixed DC potential. Current flow into the cell is  
15 then determined by the electrical characteristics of the cell, including the internal resistance of the cell. Practically, when charging the cell, the current initially has a relatively high value, and then reduces down, in some approximate exponential fashion.

Similar characteristics can be observed when discharging  
20 the cell, and all secondary cells have characteristic curves indicating the potential provided vs. charge remaining. Additionally, the potential available will depend upon the current being drawn from the cell, which in turn depends upon the cell's internal resistance.

The available power or charge that can be withdrawn from  
25 a cell will depend upon the discharge characteristics, and in particular whether a small or large current is drawn from the cell. These aspects of discharging a secondary battery or cell are disclosed in applicant's copending application, filed simultaneously herewith, under the title "Method and Apparatus for Discharging a Secondary Battery".

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**SUMMARY OF THE INVENTION**

What the present inventor has realized is that both for charging and discharging a battery, conventional techniques lead to much wastage of energy. Conventionally, as noted above, both for charging and  
5 discharging, current is drawn off essentially as a constant DC current (for practical applications, discharging will often result in a varying or intermittent current; but the essentially DC nature of the discharge certainly does not amount to a pulsed discharge as taught by the present invention and as detailed below).

10 What the present inventor has realized is that, for both charging and discharging, one can identify an apparent resonant effect. At the atomic level, it is believed that charging and discharging essentially requires ionization (or the reverse) of individual atoms or molecules. If such ionization is effected by application of a constant DC potential, often  
15 ionization is effected at a less than optimum state, thus requiring excess energy and wastage of energy. On the other hand, if ionization is, in effect, synchronized with an optimum state of the particular atom or molecule, then less energy is required.

At a macroscopic level, the inventor has discovered that  
20 this appears as a resonant effect. Thus, for charging, the inventor has discovered that if the series or train of pulses is applied during the charging process, then much more efficient charging can be obtained. In effect, between each pulse, the battery or cell is permitted to relax, and when the next pulse is applied, atoms or molecules are in an optimum state for  
25 receiving a charge.

In accordance with a first aspect of the present invention, there is provided a method of charging a secondary cell, the method comprising: supplying a DC voltage as a series of pulses to the secondary cell.

30 Preferably, the method comprises selecting values at least two of the frequency, pulse width and amplitude of each pulse, to optimize

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charging of the battery, or selecting values of all of the frequency, pulse width and amplitude of the pulses, to optimize charging of the battery.

The method advantageously includes providing the pulses as a continuous pulse train comprising a plurality of consecutive periods, wherein each period comprises a plurality of pulses, wherein the value of at least one of the frequency, the pulse width and the pulse amplitude varies within each period, and wherein all of the periods have substantially identical pulse profiles.

Another aspect of the present invention provides an apparatus for charging a battery, the apparatus comprising:  
an electronic control unit for generating a pulse train; and  
a charge device, for providing a connection to secondary cells.

Preferably, the electronic control unit includes means for selectively setting at least two of the frequency, pulse width and pulse height of the pulse train.

The electronic control unit preferably includes means for generating the pulse train as a plurality of consecutive periods, wherein each period comprises a plurality of pulses, wherein the value of at least one of the frequency, the pulse width and the pulse amplitude varies within each period, and wherein all of the periods have substantially identical pulse profiles.

#### **BRIEF DESCRIPTION OF THE DRAWING FIGURES**

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, which shows a preferred embodiment of the present invention and in which:

Figure 1 is a schematic of an apparatus in accordance with the present invention; and

Figure 2 is a graph showing an exemplary pulse train over one period.

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**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring to Figure 1, there is shown an apparatus in accordance with the present invention, the apparatus including a basic transformer and rectifier unit 1, as is common for any secondary-battery  
5 charger. The transformer and rectifier 1 is connected to a plug 2, shown schematically, by leads or wires 3. The plug 2, in known manner is adapted for connection to a standard alternating current supply. The unit 1 then transforms the alternating supply to a suitable potential and rectifies this potential to provide a DC output.

10 Leads 4 connect the DC output signal from the transformer and rectifier 1 to an electronic control unit 5 in accordance with the present invention. As detailed further below, the electronic control unit 5 is adapted to modulate the DC signal with a pulse train.

The electronic control unit 5 is connected by leads 6 to a  
15 charger unit 7. As for conventional chargers, the charger unit 7 is adapted to receive at least one secondary cell, and preferably adapted to receive a plurality of such secondary cells as indicated at 8.

The electronic control unit 5, as mentioned, is adapted to modulate the DC signal received through the wires or leads 4 with a pulse  
20 train. This pulse train essentially comprises a sequence of a large number of pulses, each of which can have differing characteristics, in terms of pulse widths and pulse height or voltage amplitude. The period between the pulses or pulse frequency is constant over the complete cycle. At least one, and preferably two, of these parameters (pulse width, frequency and voltage)  
25 can be selected and then modified to give the best result.

The complete cycle of pulses is continuously repeated, so as to provide a continuous pulse train.

What the inventor has discovered is that there is an algorithm relating the parameters of the pulse train to the charging  
30 behaviour of the cells 8. The principal parameters of the pulse train are: frequency, pulse width, and voltage or pulse height. Here, it is assumed that the pulses have a generally sinusoidal shape, but in general rectangular

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or other pulse profiles are expected to be suitable.

Various strategies can be used to examine this algorithm or determine its characteristics. For example, while maintaining the voltage constant, the pulse width and frequency can be varied.

5 The attached figure 2 shows an exemplary profile of the pulse train or signal provided by the electronic control unit 5. This shows a single period or cycle 20, and it will be understood that this period 20 is repeated to form the continuous signal.

10 Figure 2 shows exemplary pulse wave forms over a period 20. Within this period 20, there are 5 individual pulses, labelled 21, 22, 23, 24 and 25. Following each pulse, there is a respective pulse interval, labelled at 21a, 22a, 23a, 24a and 25a. In this example, these intervals have the parameters given in the following table and shown in the drawing.

**TABLE 1**

Pulse Number	Pulse Voltage	Pulse Duration	Pulse Interval
21	1.3	0.7	4 ms
22	1.4	0.8	5 ms
23	1.5	0.9	6 ms
24	1.6	0.1	7 ms
25	1.9	0.1	10 ms

15 As this table shows, within the period 20, all the parameters of the pulses, namely frequency (i.e. inverse of the pulse interval), pulse width or duration, and pulse height (voltage) are varied. This gives a distinct pulse profile for the period, and this is repeated in following periods. In general, depending on the particular application, it may not be  
 20 necessary to vary all three parameters, and it may be sufficient to vary just two of them, or even just one of them, with the other(s) being kept

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constant. Additionally, it will be understood that the absolute magnitude of each of these parameters can vary greatly depending upon the actual application. Also, a variety of pulse profiles can be used.

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**CLAIMS:**

1. A method of charging a secondary cell, the method comprising: supplying a DC voltage as a series of pulses to the secondary cell.
  - 5 2. A method as claimed in claim 1, wherein the method comprises selecting values at least two of the frequency, pulse width and amplitude of each pulse, to optimize charging of the battery.
  3. A method as claimed in claim 2, which includes selecting values of all of the frequency, pulse width and amplitude of the pulses, to  
10 optimize charging of the battery.
  4. A method as claimed in claim 1, 2 or 3, which includes providing the pulses as a continuous pulse train comprising a plurality of consecutive periods, wherein each period comprises a plurality of pulses, wherein the value of at least one of the frequency, the pulse width and the  
15 pulse amplitude varies within each period, and wherein all of the periods have substantially identical pulse profiles.
  5. An apparatus for charging a battery, the apparatus comprising:  
an electronic control unit for generating a pulse train; and  
20 a charge device, for providing a connection to secondary cells.
  6. An apparatus as claimed in claim 5, wherein the electronic control unit includes means for selectively setting at least two of the frequency, pulse width and pulse height of the pulse train.
  - 25 7. An apparatus as claimed in claim 6, wherein the electronic
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control unit includes means for generating the pulse train as a plurality of consecutive periods, wherein each period comprises a plurality of pulses, wherein the value of at least one of the frequency, the pulse width and the pulse amplitude varies within each period, and wherein all of the periods  
5 have substantially identical pulse profiles.

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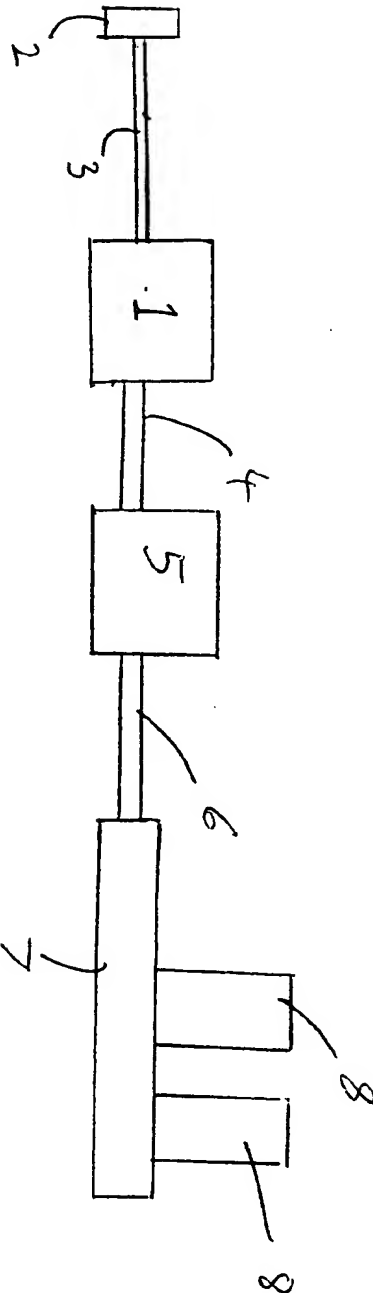


Figure 1

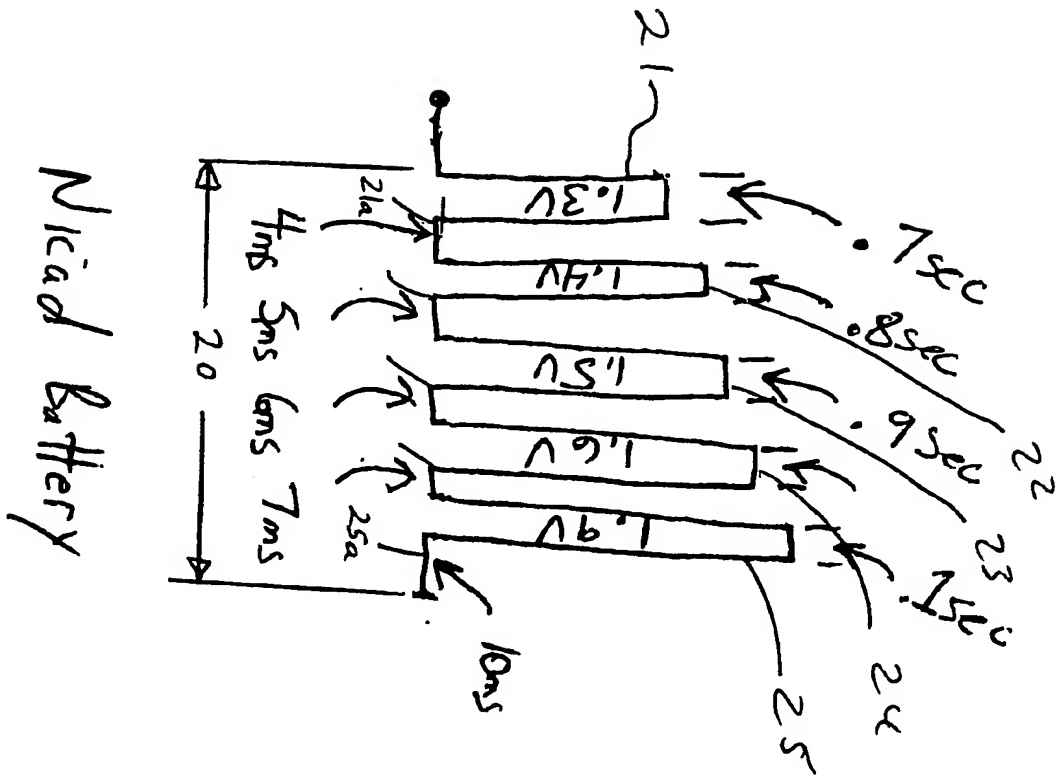


Figure 2